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Influence of Forest Type and Climate Factors on the Number of Caught *Ips typographus* (Coleoptera, Curculionidae) Bark Beetles in Pheromone Traps in Protected Areas of Bosnia and Herzegovina

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ABSTRACT

As part of the research, the population of the eight-toothed spruce bark beetle in different types of forests in five protected areas in Bosnia and Herzegovina was analyzed. The study focused on the protected areas of Sarajevo Canton, specifically the secondary forests of fir and spruce, as well as the mixed forests of beech and fir (containing spruce). Pheromone traps were used as the research sample, and they were placed within PA Bijambara, PA Trebević, and PA Skakavac. The objective was to investigate the influence of forest type and climatological factors on the number of captured *Ips typographus* bark beetles from 2018 to 2021. The average number of captured *I. typographus* bark beetles during that period ranged from 491.39 to 901.68 individuals in secondary fir and spruce forests, and from 201.88 to 701.54 individuals in beech and fir forests (including spruce).

Keywords: eight-toothed spruce bark beetle; spruce; beech; fir; pheromone traps; climatological factors

INTRODUCTION

Currently, around the world, 19 million square kilometers, or approximately 12.5% of terrestrial areas are protected. In Bosnia and Herzegovina (BiH), this percentage is around 1.5% (Annonimus 2012) and protected forest areas cover an area of 18,232.30 hectares, which is approximately 0.7% of the total area of BiH (Beus and Vojniković 2007). There are a total of 7 legally protected areas predominantly characterized by coniferous forests, with spruce (*Picea abies* (L.) H. Karst.) being the dominant species. It is known that various harmful abiotic and biotic factors can significantly affect the health of coniferous forests under certain conditions. The most common abiotic factors are climate and soil-related, while fungal diseases and bark beetles are the primary biotic factors. Bark beetles are of high ecological importance, as the majority of species live in dead or dying plants, thus being the early decomposers in forest ecosystems (Raffa et al. 2015). At the same time, bark beetles are perceived as forest pests that destroy and weaken trees (Gregoire et al. 2004, Raffa et al. 2015, Schebeck et al. 2023), where in specific conditions, like drought periods, they weaken the vitality of whole forests. In coniferous forests, bark beetles directly or indirectly can cause the drying out of more than 50% of trees (Wood 1982). One of the most well-known and dangerous pests for spruce with the potential to cause high economic losses in the forest ecosystems is the spruce bark beetle *Ips typographus* L. (Coleoptera, Curculionidae, Scolytinae) (Wermelinger 2004). Although it is primarily considered as a secondary pest (Wermelinger 2004, Dautbašić et al. 2018, Netherer et al. 2019), in specific conditions it can build high population levels, killing huge numbers of trees in a short time. Such mass outbreaks are usually a consequence of different events like abiotic disturbances, such as wind-throw, snow-break or drought (de Groot et al. 2019), in forests where suitable material for wood production is being build. Climate change and extreme drought along with secondary attacks of bark beetles eventually lead to enlargement of population levels of bark beetles which then attack healthy trees. Such increase of bark beetle population in conifers is very well known and documented in European forestry (Hlasny et al. 2014, Nikolov et al. 2014, Dautbašić et al. 2018, Hlavkova et al. 2022, Hroššo et al. 2020, Vilardo et al. 2022).

In BiH *I.typographus* has two generations per year, with the first occurring in April and the second in July when a single female can deposit between 30 to 100 eggs. Mostly they attack the lower parts where the bark is thicker (Zahirović et al. 2016). Under favourable conditions, it can have a third generation as well. The attack lasts from April to September, after which it burrows under the bark and litter where it overwinters (Tomiczek et al. 2007, Zubrik et al. 2017, Dautbašić et al. 2018). Affected trees die very fast after exit holes appear.

The adult beetle of *I. typographus* is dark brown or black with punctured lines on its wing covers, and on each side of the elytra there are four teeth. It measures approximately 5.5 mm in length. The gallery system beneath the bark is created by the females during egg-laying and by the larvae during their development, and it is usually one- or two-branched, occasionally three-branched. The length of the galleries depends on the intensity of the bark beetle attack, with shorter galleries indicating a stronger infestation and vice versa. The entire gallery system is located within the bark (Tomiczek et al. 2007, Zubrik et al. 2017, Dautbašić et al. 2018). Trees poses a defence mechanism, e.g. resin flow, and after bark beetles overcome and establish a mating chamber in the phloem they start releasing aggregation pheromones, attracting males and females (Francke et al. 1977, Byers et al. 1998). Syntheses for commercial production of the pheromone were developed in order to use the pheromones as bait in traps (Bakke 1983). Pheromone traps are primarily used for monitoring, although there have been attempts at pest control as well (Bakke et al. 1987).

Pheromone traps constitute a system composed of various housing designs that physically capture individuals and contain a chemical attractant - semiochemicals, to lure specific bark beetle species. There is a broad range of semiochemicals (Borden 1977), including pheromones that are released and received by individuals from the same species, and allelochemicals that mediate communication between species (Nordlund and Lewis 1976). The latter are further divided into kairomones, which are released by one species (e.g. host trees) and are to the benefit of the receiver of another species (e.g. bark beetles), allomones, which are beneficial for the emitter of another species, and synomones, which are to the benefit of both the sender and the receiver species (Nordlund and Lewis 1976).

The attractant Pheroprax has been developed for *I. typographus* and is widely used in forestry practices (Zuber and Benz 1992). This study aimed to determine the intensity of *I. typographus* infestation in different protected areas. The study investigated the influence of forest type and climatological factors on the number of caught *I. typographus* bark beetles.

MATERIALS AND METHODS

Field Work

Out of 7 legally protected areas in Bosnia and Herzegovina (Annonimus 2016), five are located in the Sarajevo Canton: Vrelo Bosne (603 hectares), Skakavac (1,430 hectares), Bijambare (497 hectares), Trebević (400 hectares) and Bentbaša (160 hectares). The determination of catches of *I. typographus* within the protected areas of Sarajevo Canton was conducted over a four-year period between 2018 and 2021 and was carried out in Bijambare (44.09283, 18.50049), Trebević (43.79736, 18.48032), and Skakavac (43.94803, 18.45249). For the catch of *I. typographus* Theysohn® pheromone traps and the Pheroprax® pheromone attractant (BASF Agro B.V Wadenswil, Switzerland) were used. The traps were positioned at a minimum distance of 20 m (± 2 m) from the nearest live coniferous trees. Counting the bark beetles and emptying the traps were carried out every 10-15 days. In the Bijambare protected area, 7 traps were installed during the period of 2018-2020, and 25 traps in 2021. In the Trebević protected area, 6 traps were installed during the period of 2018-2020. In the Skakavac protected area, 9 traps were installed in 2018, 6 traps in 2019, 14 traps in 2020, and 19 traps in 2021 (Figure 1). The traps were placed within two different types of forests: i) secondary forests of fir and spruce, and ii) mixed forests of beech and fir (with spruce). The analysis of trap catches was conducted at the laboratory of the Faculty of Forestry, University of Sarajevo. The distance between traps and healthy standing spruce trees was never under 20 m.

Laboratory Work

For measurement purposes, it was assumed that out of the collected bark beetles in 1 ml tube, there were 40 individuals of *I. typographus* (Hrašovec 1995). The accuracy of such assessment was tested on every twentieth sample, which showed a satisfactory level. The analysis of trap catches was conducted at the laboratory of the Faculty of Forestry, University of Sarajevo. The laboratory processing involved drying of the insects at room temperature and sorting the species under a microscope. The insects were first sorted by taxonomic categories and dried to facilitate counting. Based on the taxonomic categories, the insects were identified using available morphological keys (Pfeffer 1995). All larger insects, such as longhorn beetles, beetles with equally sized wings, and natural enemies were separated.

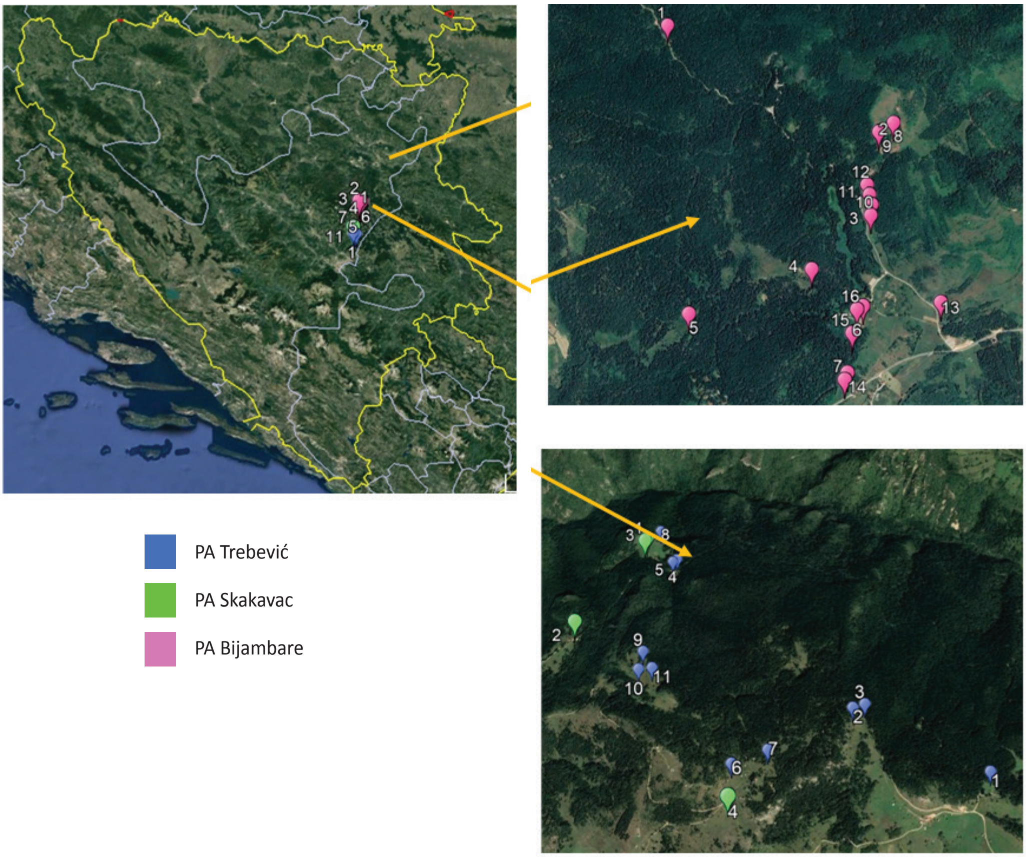

Figure 1. Position of pheromone traps: PA Trebević, PA Skakavac and PA Bijambare (Google Earth Pro).

Counting of the sorted beetles in order to confirm the accuracy of the assessment was done manually. In this work we present only data for *I. typographus*.

Statistical Analysis

The analysis was conducted using the SPSS software (ver. 20), and in addition to descriptive statistics, testing of the mean statistical significance (ANOVA) and Tukey HSD test were performed to determine the strength of the impact of forest type and climatological factors on the number of captured *I. typographus* individuals.

RESULTS

The study revealed that the average number of *I. typographus* individuals in 2018 ranged from 0 to 371.43 (average 266.40) in PA Bijambare, from 0 to 2589.41 (average 1130.79) in PA Trebević, and from 0 to 677.78 (average 474.67) in PA Skakavac. In 2019, the average number of *I. typographus* individuals ranged from 0 to 2511.43 (average 778.57) in PA Bijambare, from 0 to 1748.89 (average 988.40) in PA Trebević, and from 0 to 1173.33 (average 592.38) in PA Skakavac. In 2020, the average number of *I. typographus* individuals ranged from 0 to 268.57 (average 183.21) in PA Bijambare, from 64.44 to 1636.67 (average 758.98) in PA Trebević, and from 0 to 373.33 (average 238.19) in PA Skakavac. In 2021, the average number of *I. typographus* individuals ranged from 0 to 366.51 (average 205.67) in PA Bijambare, from 0 to 958.12 (average 784.62) in PA Trebević, and from 0 to 700.70 (average 484.87) in PA Skakavac. Within this study, a total of 80,470 individuals were caught in the Bijambare protected area, 346,880 individuals in the Trebević protected area, and 137,090 individuals in the Skakavac protected area. Figures 2-5 show the catch of *I. typographus* bark beetles by month for the period 2018-2021 in the respective protected areas.

To analyse the impact of forest type on the number of captured *I. typographus* individuals, a test of statistical significance of mean differences was conducted. Table A1 presents the mean and standard deviation of bark beetle catches for the years 2018-2021 across different protected areas.

To determine the statistical significance of differences in bark beetle catches for the period 2018-2021 across

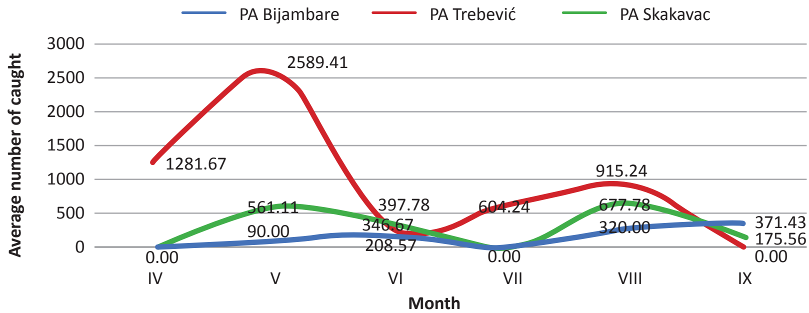

Figure 2. Average number of caught *I. typographus* bark beetles in 2018.

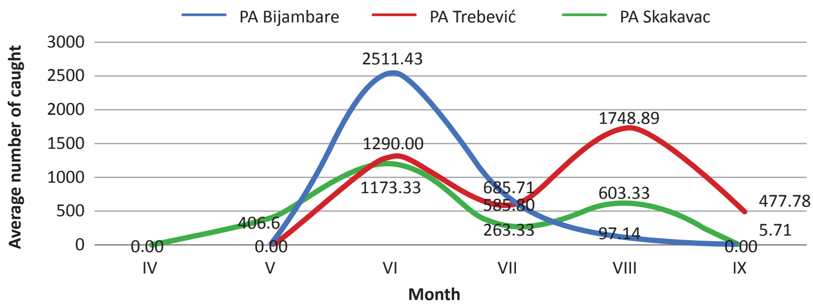

Figure 3. Average number of caught *I. typographus* bark beetles in 2019.

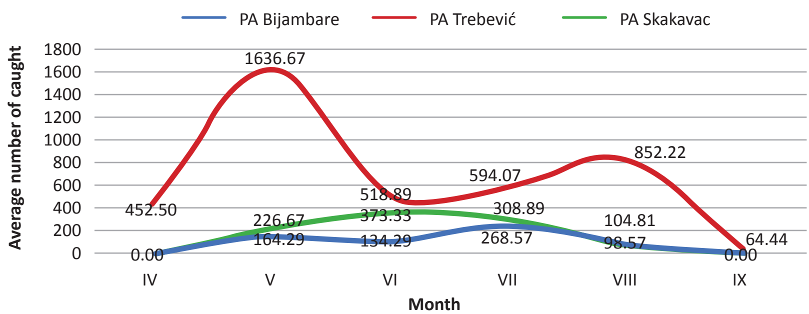

Figure 4. Average number of caught *I. typographus* bark beetles in 2020**.**

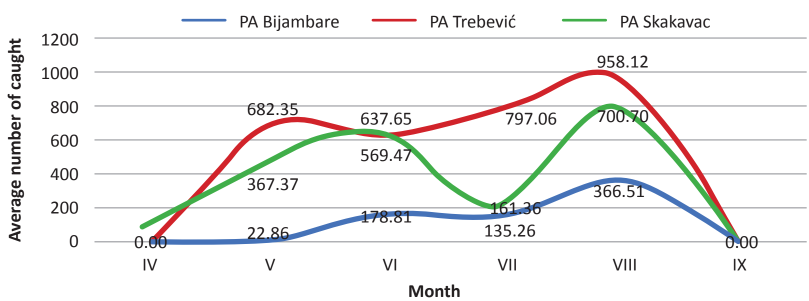

Figure 5. Average number of caught *I. typographus* bark beetles in 2021.

different protected areas, a one-way analysis of variance (ANOVA) was performed. The null hypothesis was set as follows: "There are no statistically significant differences in the average catches of *I. typographus* bark beetles for the period 2018-2021 across different protected areas at a probability of p<0.05." The results of the analysis are presented in Table A2.

The statistical analysis conducted revealed statistically significant differences in the average catches of *I. typographus* bark beetles for the years 2018, 2020, and 2021 across different protected areas, at a probability level of p<0.05. However, no statistical significance was found in the average catches of *I. typographus* bark beetles for the year 2019 across different protected areas (Table A3).

According to the Tukey HSD test, a difference in the average catches of *I. typographus* was found in 2018 between the PA Bijambare and PA Trebević, and between PA Trebević and PA Skakavac. In 2019, no differences in the average catches of *I. typographus* were found. In 2020, a difference in the average catches of *I. typographus* was found between PA Bijambare and PA Trebević, and between PA Trebević and PA Skakavac. In 2021, a difference in the average catches of *I. typographus* was found between PA Bijambare, PA Trebević, and PA Skakavac.

Figures 6-9 depict the catches of *I. typographus* by month and by forest type for the period 2018-2021.

In order to analyse the effect of forest type on the number of captured individuals of *I. typographus*, a test of statistical significance was conducted to examine the differences in means. Table A4 presents the arithmetic mean and standard deviation of the catches of bark beetles for the years 2018-2021, according to different forest types.

To determine the statistical significance of differences in the catch of bark beetles for the period 2018-2021, depending on the forest type, a test of one-way analysis of variance (ANOVA) was conducted. The null hypothesis was set as follows: "There are no statistically significant differences in the average catches of *I. typographus* for the period 2018-2021, depending on the forest type, at a probability level of p<0.05." The results of the analysis are presented in Table A5.

The conducted statistical analysis determined that there are statistically significant differences in the average catches of *I. typographus* for the years 2020 and 2021, depending on the forest type, at a probability level of p<0.05. However, no statistical significance was found between the average catches of *I. typographus* for the years 2018 and 2019, depending on the forest type.

To determine the statistical significance of differences in the catch of bark beetles for the period 2018-2021, depending on climatological factors, a test of one-way analysis of variance (ANOVA) was conducted. The null hypothesis was set as follows: "There are no

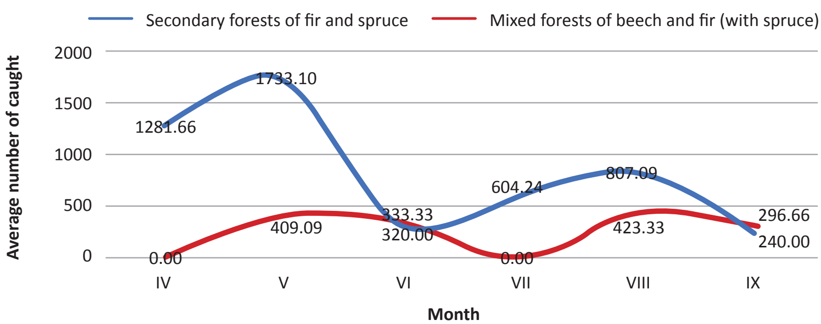

Figure 6. Average number of caught *I. typographus* bark beetles in 2018.

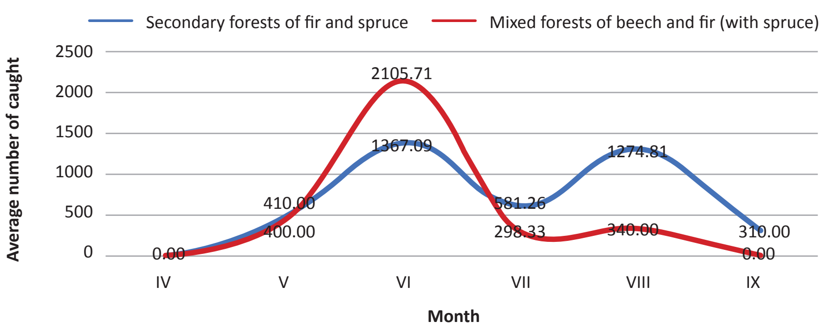

Figure 7. Average number of caught *I. typographus* bark beetles in 2019.

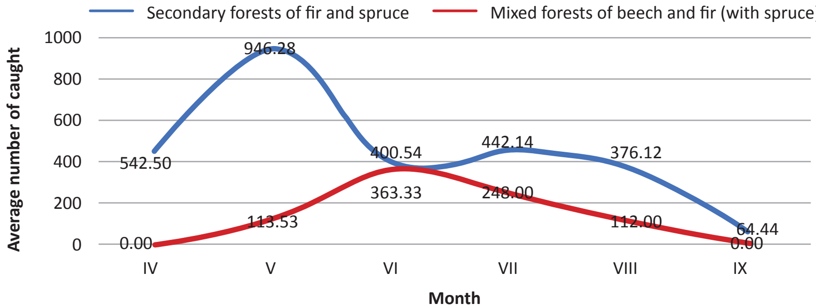

Figure 8. Average number of caught *I. typographus* bark beetles in 2020.

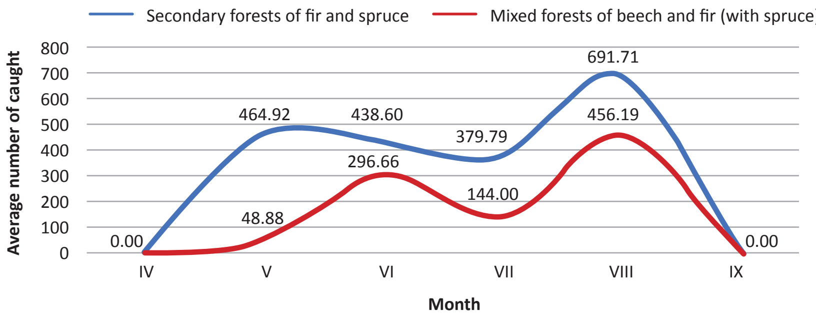

Figure 9. Average number of caught *I. typographus* bark beetles in 2021.

statistically significant differences in the average catches of *I. typographus* for the period 2018-2021, depending on climatological factors, at a probability level of $p<0.05$." The results of the analysis are presented in Tables A6-A9.

The conducted statistical analysis determined that there are no statistically significant differences in the average catches of *I. typographus* for the years 2018 and 2019, depending on climatological factors, at a probability level of $p<0.05$. However, statistical significance was found between the average catches of I. *typographus* for the year 2020, depending on the mean annual temperature and the maximum temperature of the warmest month. Statistical significance was also found between the average catches of *I. typographus* for the year 2021, for all parameters.

DISCUSSION

Despite available technologies, so far semiochemical-based tools have been comparatively rarely used in agriculture and forestry, and conventional insecticides as the historically only alternative decreased in acceptance due to their environmental, social, and human health impact, so more sustainable alternatives are urgently needed (Pernek 2002, Gillette and Fettig 2021, Mafra-Neto et al. 2022).

This study encompassed the catch of *I. typographus* as an indicator of infestation in different protected areas of the Sarajevo Canton, as well as in different forest types. The focus of the research was to analyse the influence of year, forest type and climatological factors in the protected areas and forest type on the population abundance of *I. typographus*. The significance of this research lies in the analysis of the catch of *I. typographus* in different protected areas of the Sarajevo Canton, Bosnia and Herzegovina. The Pheroprax pheromone was used to determine the infestation intensity. The same pheromone was used for the catch of *I. typographus* by other researchers as well (Pernek 2002, Gillette and Fettig 2021, Mafra-Neto et al. 2022). Zahirović et al. (2016) found in their research that the average number of *I. typographus* caught on Theysohn® traps ranged from 2.04 to 966.41. The average number of *I. typographus* caught per trap in this study was significantly higher, reaching up to 2332.81 individuals, which can be partially attributed to the population outbreak of this bark beetle during the years of the research.

A one-way analysis of variance was performed to test the difference between the average catches of *I. typographus* depending on the protected area, revealing differences in the years 2018, 2020, and 2021. In 2018 and 2020, differences in catches were found between all protected areas, while in 2021, differences were found between PA Bijambare, PA Trebević, and PA Skakavac. One assumption for these results is that in all three protected areas, a higher number of traps were placed in secondary spruce and fir forests compared to beech and fir (with spruce) forests, resulting in higher catches of the bark beetle.

To determine the statistical significance of differences in bark beetle catches for the period 2018-2021, it was found that there are statistically significant differences in the average catches of *I. typographus* for 2020 and 2021, while no significant differences were found for 2018 and 2019, depending on the forest type. The study revealed that the catch of *I. typographus* was twice as high in secondary spruce and fir forests compared to beech and fir (with spruce) forests. One assumption for such a result is that there is a higher proportion of spruce trees in secondary spruce and fir forests, thereby providing a greater number of hosts for the bark beetle's development. Studies have shown that non-host tree species diversity per se is not the main driver of outbreak risk, but that it strengthens biotic resistance with lower host availability at low altitudes where abiotic conditions are the least favorable to Norway spruce (de Groot et al. 2023).

Furthermore, the catch of bark beetles was investigated in relation to climatological factors, and for the years 2018 and 2019, no influence of climatological factors on the average bark beetle catch was determined. In 2020, the influence of the mean annual temperature and the maximum temperature of the warmest month on the average catch of *I. typographus* was determined. In 2021, the influence of the mean annual temperature, maximum temperature of the warmest month, minimum temperature of the coldest month, mean temperature of the wettest quarter, annual precipitation, and precipitation in the wettest and driest month on the average catch of *I. typographus* was determined. In his research, Faccoli (2009) also did not find an influence of precipitation during the activity period of *I. typographus* and the damage caused by this bark beetle throughout the year (Faccoli 2009). However, he found that increased damage occurred one year later if the precipitation was below the 10-year average. This leads us to the conclusion that precipitation, depending on climatic factors, directly and indirectly affects the population of *I. typographus*. Changes in climate factors can cause a sudden change in the behaviour of bark beetles, i.e. a sudden population growth (Pernek et al. 2019).

An appropriately established monitoring system makes it possible to take timely protective measures to prevent or reduce to the lowest possible level a more severe bark beetle infestation in protected areas. Timely detection of bark beetles gives companies managing protected areas sufficient space and time to respond in time to suppress bark beetle infestations. It should be remembered that the company managing protected areas in the territory of Sarajevo Canton does not have its own employees to perform the tasks of felling and exporting the felled trees, but third parties have to be contracted for these tasks. All this significantly slows down the process of rehabilitation of bark beetle infestation, which is why the monitoring system is the main line of defence when it comes to protecting forests from bark beetle infestation in protected forest areas.

In the future, further research will be needed on bark beetle catches in different protected areas, different forest types, and their relationship with various climatological factors in Bosnia and Herzegovina.

CONCLUSIONS

Based on the conducted research, the following conclusions can be drawn: The study analysed the catch of *I. typographus* in pheromone traps in the protected areas in Bosnia and Herzegovina with respect to different forest types and climatological factors. During the period of 2018-2021, the number of caught *I. typographus* where statistically significant among five studied protected areas. In the period of 2018-2021, a higher average number of caught *I. typographus* individuals were found in secondary forests of fir and spruce compared to beech and fir forests (with spruce). Statistically significant differences in the average catch of *I. typographus* were observed for the years 2020 and 2021, depending on the forest type, while no significant differences were found for 2018 and 2019. There were no statistically significant differences in the average catch of *I. typographus* bark beetles for the years 2018 and 2019 concerning climatological factors, while for 2020, statistical significance was found in relation to the mean annual temperature and maximum temperature of the warmest month. Additionally, for 2021, statistical significance was observed for all parameters. This work is important because it talks about the health condition of forests in protected areas, as well as the monitoring of harmful insects in them. Further research is needed on the catch of bark beetles in protected areas in Bosnia and Herzegovina.

Author Contributions

OM, KZ, AV, DP, SI conceived and designed the research, OM and KZ carried out the field measurements, KZ performed laboratory analysis, KZ, AV and DP processed the data and performed the statistical analysis, MD and MP secured the research funding, supervised the research and helped to draft the manuscript, all authors wrote the manuscript.

Funding

This work was financed from our own resources.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Table A1. Arithmetic mean and standard deviation for *I. typographus* catches from the period 2018 – 2021 for different protected areas.

Protected area		2018	2019	2020	2021
Protected area Bijambare	Mean	266.40	778.57	183.21	205.67
	N	25	42	56	150
	Std. Deviation	211.00	1254.13	202.41	199.06
Protected area Trebević	Mean	1130.79	988.40	758.98	784.62
	N	89	81	98	117
	Std. Deviation	1662.07	1143.64	904.58	599.90
Protected area Skakavac	Mean	474.67	592.38	238.19	484.87
	N	45	42	72	152
	Std. Deviation	437.29	770.58	297.47	497.37
Total	Mean	809.18	834.18	450.40	468.62
	N	159	165	226	419
	Std. Deviation	1317.33	1098.71	681.43	506.18

Table A2. Analysis of variance (ANOVA) of statistically significant differences in *I. typographus* catches depending on the protected area.

		Sum of Squares	df	Mean Square	F	Sig.
2018 * *Protected area*	Between Groups(Combined)	21606052.77	2	10803026.38	6.672	0.002
	Within Groups	252580940.94	156	1619108.59		
	Total	274186993.71	158			
2019 * *Protected area*	Between Groups(Combined)	4511846.99	2	2255923.49	1.889	0.155
	Within Groups	193465767.54	162	1194233.13		
	Total	197977614.54	164			
2020 * *Protected area*	Between Groups(Combined)	16571679.49	2	8285839.74	21.019	0.000
	Within Groups	87908384.66	223	394208.00		
	Total	104480064.15	225			
2021 * *Protected area*	Between Groups(Combined)	22094608.74	2	11047304.37	54.064	0.000
	Within Groups	85005188.39	416	204339.39		
	Total	107099797.13	418	10803026.38		

Table A3. Multiple tests of average differences in the catch of *I. typographus* bark beetles for 2018, 2019, 2020 and 2021 depending on the protected area (Tukey HSD).

Dependent variable	Proceed area (A)	Proceed area (B)	Mean Difference (A-B)	Std. Error	Sig.
2018	Bijambare	Trebević	-864.387*	288.022	.009
		Skakavac	-208.267	317.403	.789
	Trebević	Bijambare	864.387*	288.022	.009
		Skakavac	656.120*	232.750	.015
	Skakavac	Bijambare	208.267	317.403	.789
		Trebević	-656.120*	232.750	.015
2019	Bijambare	Trebević	-209.824	207.793	.572
		Skakavac	186.190	238.471	.715
	Trebević	Bijambare	209.824	207.793	.572
		Skakavac	396.014	207.793	.140
	Skakavac	Bijambare	-186.190	238.471	.715
		Trebević	-396.014	207.793	.140
2020	Bijambare	Trebević	-575.765*	105.176	.000
		Skakavac	-54.980	111.868	.875
	Trebević	Bijambare	575.765*	105.176	.000
		Skakavac	520.785*	97.456	.000
	Skakavac	Bijambare	54.980	111.868	.875
		Trebević	-520.785*	97.456	.000
2021	Bijambare	Trebević	-578.949*	55.756	.000
		Skakavac	-279.202*	52.025	.000
	Trebević	Bijambare	578.949*	55.756	.000
		Skakavac	299.747*	55.595	.000
	Skakavac	Bijambare	279.202*	52.025	.000
		Trebević	-299.747*	55.595	.000

(*) The differences in the catches of I. typographus depending on the protected area are highly statistically significant at a probability of 0.05.

Table A4. Arithmetic mean and standard deviation for the catch of *I. typographus* bark beetle from the period 2018 – 2021 for different forest types.

Type of forest		2018	2019	2020	2021
Secundary forests of fir and spruce	Mean	901.68	858.99	491.39	507.44
	N	131	139	194	351
	Std. Deviation	1424.24	1077.89	721.49	528.72
Mixed forests of beech and fir (with spruce)	Mean	376.43	701.54	201.88	268.24
	N	28	26	32	68
	Std. Deviation	390.67	238.90	234.91	299.17
Total	Mean	809.18	834.18	450.40	468.62
	N	159	165	226	419
	Std. Deviation	1317.33	1098.71	681.43	506.18

Table A5. Analysis of variance (ANOVA) of statistically significant differences in *I. typographus* catches depending on forest type.

		Sum of Squares	df	Mean Square	F	Sig.
2018 * Type of forest	Between Groups(Combined)	6364520.31	1	6364520.31	3.731	0.055
	Within Groups	267822473.40	157	1705875.62		
	Total	274186993.70	158			
2019 * Type of forest	Between Groups(Combined)	543017.09	1	543017.09	0.448	0.504
	Within Groups	197434597.50	163	1211255.19		
	Total	197977614.50	164			
2020 * Type of forest	Between Groups(Combined)	2302452.43	1	2302452.43	5.048	0.026
	Within Groups	102177611.70	224	456150.05		
	Total	104480064.20	225			
2021 * Type of forest	Between Groups(Combined)	3259316.59	1	3259316.59	13.089	0.000
	Within Groups	103840480.50	417	249017.93		
	Total	107099797.10	418			

Table A6. Analysis of variance (ANOVA) of statistically significant differences in *I. typographus* catches depending on climatological factors in 2018.

		Sum of Squares	df	Mean Square	F	Sig.
The average annual temperature	Between Groups(Combined)	32.136	60	.536	.909	.651
	Within Groups	57.723	98	.589		
	Total	89.858	158			
The max temperature of the warmest month	Between Groups(Combined)	98.076	60	1.635	.944	.591
	Within Groups	169.771	98	1.732		
	Total	267.847	158			
The min temperature of the coldest month	Between Groups(Combined)	5.856	60	.098	1.437	.055
	Within Groups	6.655	98	.068		
	Total	12.511	158			
The average temperature of the most humid quarter	Between Groups(Combined)	1838.469	60	30.641	1.005	.484
	Within Groups	2988.304	98	30.493		
	Total	4826.773	158			
The annual rainfall	Between Groups(Combined)	22647.915	60	377.465	1.073	.374
	Within Groups	34489.796	98	351.937		
	Total	57137.711	158			
The rainfall in the most humid month	Between Groups(Combined)	237.150	60	3.953	.918	.636
	Within Groups	421.844	98	4.305		
	Total	658.994	158			
The rainfall in the driest month	Between Groups(Combined)	258.343	60	4.306	.970	.545
	Within Groups	435.141	98	4.440		
	Total	693.484	158			

Table A7. Analysis of variance (ANOVA) of statistically significant differences in *I. typographus* catches depending on climatological factors in 2019.

		Sum of Squares	df	Mean Square	F	Sig.
The average annual temperature	Between Groups(Combined)	34.655	71	.488	.971	.548
	Within Groups	46.746	93	.503		
	Total	81.401	164			
The max temperature of the warmest month	Between Groups(Combined)	90.850	71	1.280	.870	.729
	Within Groups	136.762	93	1.471		
	Total	227.612	164			
The min temperature of the coldest month	Between Groups(Combined)	6.052	71	.085	.963	.562
	Within Groups	8.227	93	.088		
	Total	14.279	164			
The average temperature of the most humid quarter	Between Groups(Combined)	2024.200	71	28.510	.793	.847
	Within Groups	3344.400	93	35.961		
	Total	5368.601	164			
The annual rainfall	Between Groups(Combined)	30090.603	71	423.811	.904	.670
	Within Groups	43601.724	93	468.836		
	Total	73692.327	164			
The rainfall in the most humid month	Between Groups(Combined)	291.415	71	4.104	.914	.652
	Within Groups	417.579	93	4.490		
	Total	708.994	164			
The rainfall in the driest month	Between Groups(Combined)	344.048	71	4.846	.869	.732
	Within Groups	518.800	93	5.578		
	Total	862.848	164			

Table A8. Analysis of variance (ANOVA) of statistically significant differences in *I. typographus* catches depending on climatological factors in 2020.

		Sum of Squares	df	Mean Square	F	Sig.
The average annual temperature	Between Groups(Combined)	51.713	64	.808	1.819	.001
	Within Groups	71.513	161	.444		
	Total	123.225	225			
The max temperature of the warmest month	Between Groups(Combined)	156.821	64	2.450	2.005	.000
	Within Groups	196.722	161	1.222		
	Total	353.543	225			
The min temperature of the coldest month	Between Groups(Combined)	5.505	64	.086	.913	.656
	Within Groups	15.171	161	.094		
	Total	20.676	225			
The average temperature of the most humid quarter	Between Groups(Combined)	2627.769	64	41.059	1.335	.075
	Within Groups	4950.567	161	30.749		
	Total	7578.336	225			
The annual rainfall	Between Groups(Combined)	28590.475	64	446.726	.989	.509
	Within Groups	72721.990	161	451.689		
	Total	101312.465	225			
The rainfall in the most humid month	Between Groups(Combined)	326.302	64	5.098	1.169	.217
	Within Groups	702.198	161	4.361		
	Total	1028.500	225			
The rainfall in the driest month	Between Groups(Combined)	350.155	64	5.471	1.049	.398
	Within Groups	839.774	161	5.216		
	Total	1189.929	225			

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